Portuguese Lookout Towers Network Optimization Using Automatic Positioning Algorithms

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Abstract

Although new surveillance means have been deployed in Portugal in the last few years, such as automatic detection camera systems, the National Lookout Towers Network (NLTN) is still the main organized fire detection system, having a total of 236 observation posts. These posts have been placed gradually over the last decades, resulting in a under optimized network.

To evaluate the NLTN covering effectiveness we have developed several automatic computer positioning algorithms, capable of objectively evaluating a surveillance configuration and calculate optimal changes. These algorithms run in MATLAB environment, are based on terrain elevation model data and use the cartography created by Rego and Catry to evaluate the covered area (Rego and others, 2005).

The developed algorithms were first used to create a value ranking of all the surveillance posts in the context of the current NLTN, in order to determine which should be removed. We concluded that removing 20 posts (8.5 percent), the covered area would only be reduced by 0.4 percent.

Next, the algorithms were used to automatically search the elevation model and create a database with the most valuable surveillance locations in Portugal, containing 27,244 sites. These sites were evaluated to determine which were the most valuable to add. We concluded for instance that adding 20 new posts (8.5 percent) results in a covered area increase of 6.6 percent.

Next we determined the optimal repositioning of existing posts. We concluded for instance that the optimal repositioning of the 20 less valuable posts would conceive a gain of 6.2 percent in covered area value.

The final step was to determine a new global configuration targeted to cover the same area value as the NLTN. A solution was found having only 142 surveillance posts, 39.8 percent less than the current NLTN.

In this paper we present the developed algorithms and the methodology used in evaluating and optimizing NLTN. This methodology can be applied with success in other regions with a low efficiency Towers Network.

Keywords: fire detection, lookout towers network, computer algorithms, optimization.

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Introduction

The Portuguese Lookout Towers Network (NLTN) configuration and its low efficiency are the result of the contribution of several factors. First, the network's 236 observation post's locations were chosen gradually during several decades, most times keeping the existent sites and adding new ones according to needs, obtaining an under optimized solution. Second, the zones that need surveillance have changed over the years, as new protected areas have been created and much of the agriculture production area has been converted into forests. Last, the spread of cellular phone coverage and usage has increased enormously the population's generated alerts number, mainly in densely populated areas, becoming a new NLTN competitor. These factors contributed together to the need to analyze objectively the current NLTN configuration and propose optimal changes.

Methodology

Terrain elevation model and priority cartography used

The elevation model used was originally a model released by NASA, which shown the need to be validated and adapted by Rego and others to be used in this work (NASA and others, 2004; Rego and others, 2005). This elevation model has a spatial resolution of 90 meters and was used to calculate the viewing zones given by observation sites studied.

The viewing zones used were not traditional line-of-sight areas, but lookout probabilistic areas, calculated using a new method developed by Rego (Rego and others, 2005). This new method is very complete, and includes information about several factors, including the terrain topography, earth curvature, atmospheric refraction effect, and coverage dependence on distance (Davis and others, 1959; Brown and Davis, 1973; Buckland and others, 1993, 2001; Catry, 2002, 2004).

The priority areas cartography used was created also by Rego, and has a resolution of 990 meters (Rego and others, 2005). This cartography is the result of the inclusion of several factors, including fire risk, land cover and NLTN efficiency over the last years, and can be seen in Figure 1.

Building a new possible observation post sites database

The repositioning and addition of new observation posts, as well as the creation of an all-new configuration, required the previous determination of a database with a large amount of new possible surveillance sites, from which the new proposed posts were selected. Therefore, this location's database was created, based on the elevation model and on the priorities cartography, which served as the base for the selection of new sites.

The building of this new possible locations database was made using an automatic computational observation post search algorithm. This algorithm was, as the others referred bellow, implemented in an application called SOMBRAS, and can be described by the following steps (Almeida and others, 2005):

1. Divide the target zone in regular squares;
2. Search, for every square, the highest spot and if it is a hill top save its location;

3. Build a site ranking with every location found and discard the less valuable sites, until a predetermined number of sites remain;
4. Make pairs with the remaining sites, calculate the common covered area and build a concurrence ranking; starting with the highest concurrence pairs discard the pair's less valuable site until a predetermined number of sites remain;

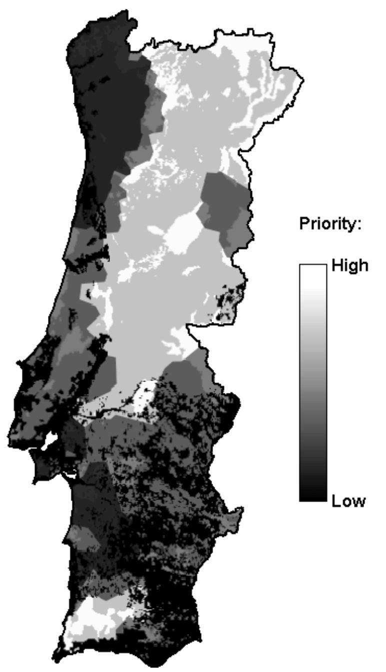

Figure 1— Cartography identifying priority areas.

The square size used in step 1 was 990 meters, the same resolution as the priorities cartography. In step two 27,244 sites were found, marked in black in Figure 2. This amount was too large, because to apply the search and relocation algorithms used afterwards we needed to have less than 1000 sites, for time and computational power constrains, so steps 3 and 4 were used to decrease this amount, choosing the best sites.

Step 3 consists on the isolated evaluation of all sites and the discard of the less valuable ones. This step is significantly more efficient then step 4, so it was interesting to eliminate as much sites as possible. However, we noticed that the less valuable sites were concentrated in few regions and its elimination would lead to a lack of possible surveillance points in these regions. So, it was not possible to discard as many sites as intended, passing a still large amount of sites to deal in step 4. Figure 3 shows the sites discarded in step 3.

After step 3 there were 25,500 sites left. Step 4 of the new site search algorithm consists in the elimination of sites based on the commonly covered area. For efficiency reasons we considered that concurrence should not be evaluated for sites separated for more than 50Km, so commonly covered areas were not calculated for site pairs with more then this distance. As the step 4 is the last step we needed to discard a large number of sites, to obtain a number that could be used in the next operations. Figure 4 shows the sites which were eliminated in step 4.

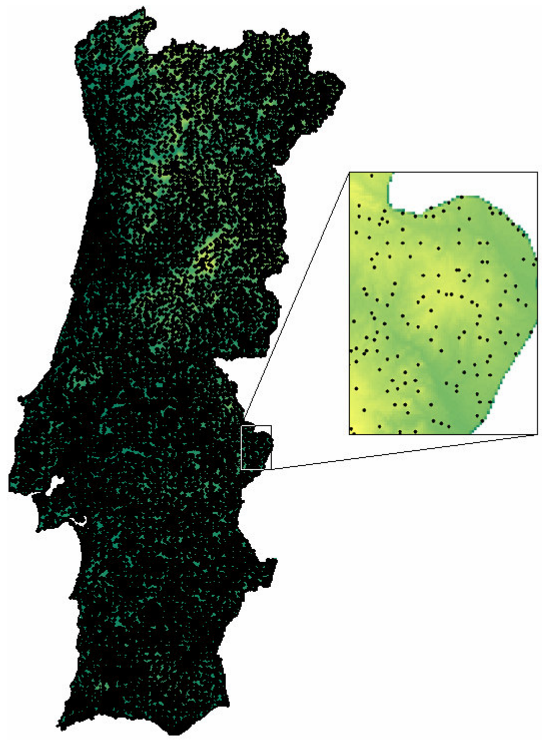

Figure 2—Distribution of all the possible surveillance sites found in the country, using the elevation model resolution.

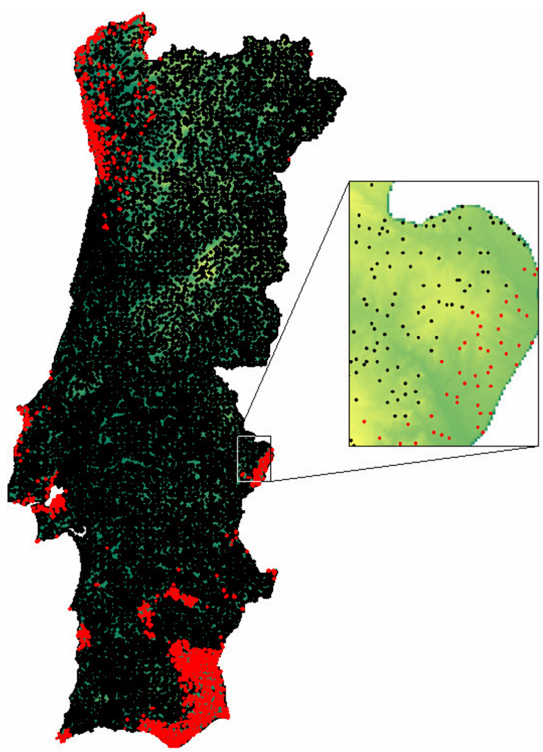

Figure 3—Sites eliminated in step 3, marked red.

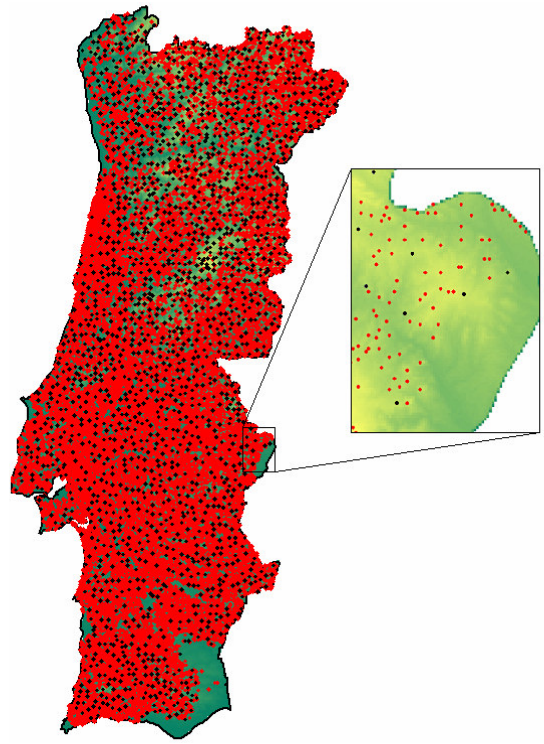

Figure 4—Sites eliminated in step 4, marked red.

The map in the Figure 4 shows the remaining sites marked black, which constitute the new observation post's location database, with 750 elements.

The sites coverage statistical distributions were also analyzed, to confirm that every step in the presented search algorithm was giving the expected results. Figure 5 presents the results, showing that the coverage distribution is improved in every step.

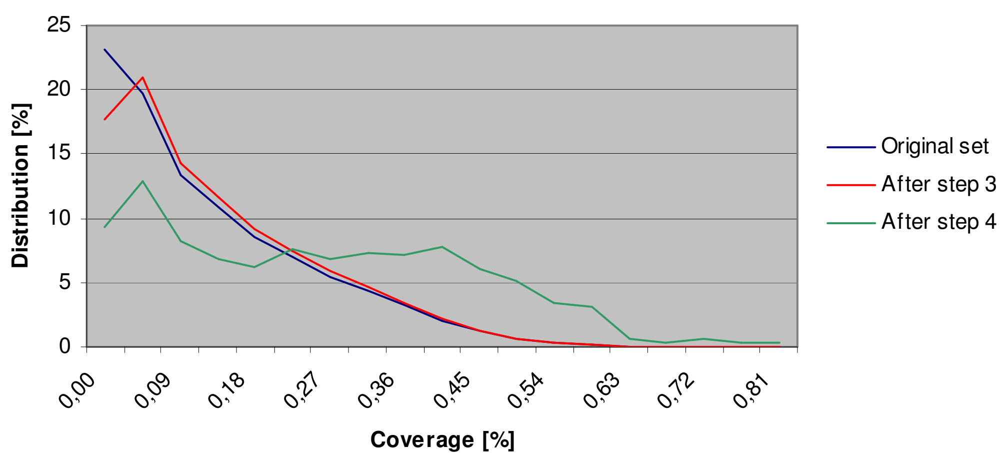

Figure 5—Site's coverage distribution, in three phases of the search algorithm.

Proposal for reducing NLTN number of sites

The calculation of the NLTN's number of sites reduction proposal doesn't involve, obviously, the need for the new site's locations database calculated before. The methodology used was to perform the objective evaluation of all the sites in the current NLTN, obtaining a value ranking. Based in this ranking it is easy to determine which sites should be removed. The site's evaluation, however, must not be individual, but in the context of the current NLTN. This lead to the usage of two different evaluation methods: the adding method and the removing method.

The adding method starts with a blank configuration and calculates the individual contribution of every site in the NLTN. The most valuable site is then added and the evaluation is repeated for the remaining sites, maintaining the first added site in the configuration. The second site is then added and the process is repeated until every sites are added. The result is a ranking starting with the most valuable site to less valuable one, which reflects the individual contribution to the overall configuration.

The removing method is similar to the adding method. It starts with the full configuration and evaluates the resulting effect of removing individually every site in this configuration. The less valuable site is then removed and the evaluation process in repeated, until there are no sites left. The result is again a value ranking of all the sites in the NLTN, which was used for the NLTN's number of sites reduction proposal.

Proposal for increasing NLTN number of sites

NLTN's number of sites increase proposal uses the results obtained in the search for new possible observation posts sites. The algorithm used in this proposal is similar to the one used in the reduction proposal to build the adding method ranking. In this case the base configuration was the current NLTN and the available sites to add were all the sites in the new possible site database. The gain of adding every site in this database individually was evaluated and the best was choose and added to the configuration. The process was repeated until a value ranking was obtained, for all the sites in the new site database.

Proposal for repositioning NLTN sites

The proposal for the repositioning of NLTN sites consisted in the removal of the less valuable sites and their replacement by new sites optimally positioned.

For the elaboration of this proposal we used methods that come in line with the already described. Starting with the current NLTN configuration and, using the already described removing method, the less valuable site was discarded, obtaining a configuration with all the NLTN sites except one. Then, the new sites database created before was searched, evaluating the contribution of every possible site in the new configuration, and the most valuable was added, obtaining again a configuration with the number of sites of the original NLTN. This process was repeated until the removed site matched the one to add, which meant that the configuration obtained could not be improved.

New global configuration proposal

The objective of building a new global configuration was not that it might be implemented, but to get a reference on how ineffective is the current solution.

It would be desirable to test all possible configurations that can be obtained with the possible sites database, but this was not possible because the total number of configurations it extremely elevated. So we needed to develop a new algorithm that, although not optimal, could lead to interesting results in valuable time. This algorithm is synthetically described in the following steps:

1. Define a subset of the target zone with a size adequate to the available computational power;
2. Using only the sites inside the subset zone, calculate the optimal configuration for the coverage of that zone, testing all possible configurations;
3. Save the calculated configuration and increase the subset zone; repeat steps 2 and 3 until all the target zone is covered;

Although this algorithm cannot in the general case output the optimal solution it guaranties partial zone optimization.

Results

NLTN number of sites reduction proposal

The two rankings obtained with the adding and the removing methods were very similar, although some differences were found in intermediary positions. Based on these rankings it is possible to remove any number of sites of the current NLTN and evaluate the results.

Although the rankings obtained for the 236 NLTN current sites are not presented here, as would not be relevant in the scoop of this paper, a concrete proposal for the reduction of 20 sites is shown next.

Figure 6 (left map) presents the 20 less valuable sites location, according to the calculated rankings. These 20 sites are the ones who give the less contribution to the overall performance, according to the referred rankings. The removal of these 20 sites corresponds to an 8.5 percent reduction in NLTN number of sites and to a mere 0.4 percent reduction in the overall coverage, which is meaningful of the very low contribution of these sites.

NLTN number of sites increase proposal

For this proposal a new ranking was created, for all the sites in the new site database. Based on this ranking it is possible to simulate the results of adding any number of sites to the current NLTN, placed in optimal positions. A concrete proposal for the addition of 20 sites is presented here.

The first site to add, according to the ranking obtained, gave a contribution of 0.55 percent, while the last, the 20^{th}, gave a contribution of 0.13%. Figure 6 (right map) shows the location of the new proposed sites, altogether with NLTN current sites.

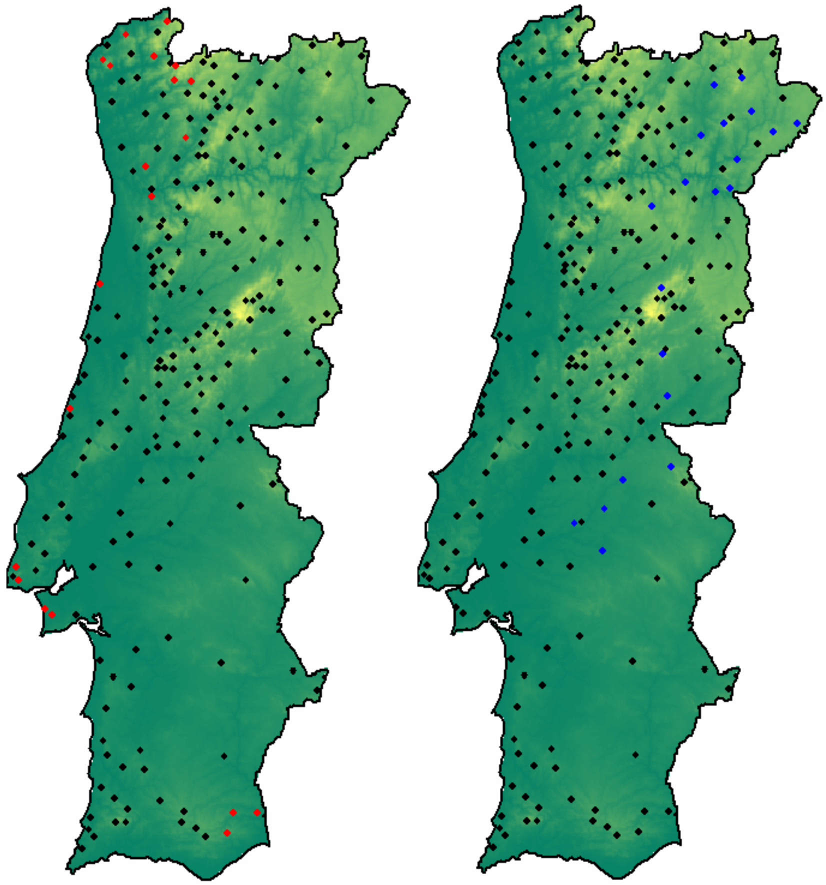

Figure 6—Left: Sites in NLTN reduction proposal, marked red. Right: Sites in NLTN increase proposal, marked blue. Current NLTN sites are marked black, in both cases.

The addition of the 20 proposed sites corresponds to an increase in NLTN sites number of 8.5 percent, and guarantees an interesting coverage increase of 6.6 percent.

NLTN sites repositioning proposal

The results for the repositioning proposal consisted in an ordered list with the sites to remove and the correspondent sites to add in their places. Using this list it is possible to simulate the repositioning of any number of sites in the NLTN, removing the less valuable posts and adding the optimally positioned ones in their places. The results obtained for the repositioning of 20 sites are presented next.

The repositioning of the first site guarantees an increase in NLTN surveillance of 0.54 percent, just below the 0.55 percent obtained with the addition of a new site. Figure 7 (left map) presents the results of repositioning the 20 less valuable sites. The resulting coverage gain was 6.2 percent, not far from the 6.6 percent gain obtained with the adding of 20 new sites.

New global configuration proposal

The appliance of the new configuration creation algorithm to the sites in the site database resulted in a configuration with 142 sites. Of these, 39 are currently in the NLTN. The new configuration obtained guarantees a global coverage of 51.8 percent, above the 50.8 percent coverage guaranteed by the current NLTN.

This result reveals a serious miss adjustment between the current NLTN sites location and the current surveillance needs, reflected in the priorities cartography used in this work (see Figure 1).

Figure 7 (right map) presents the location of the 142 calculated sites

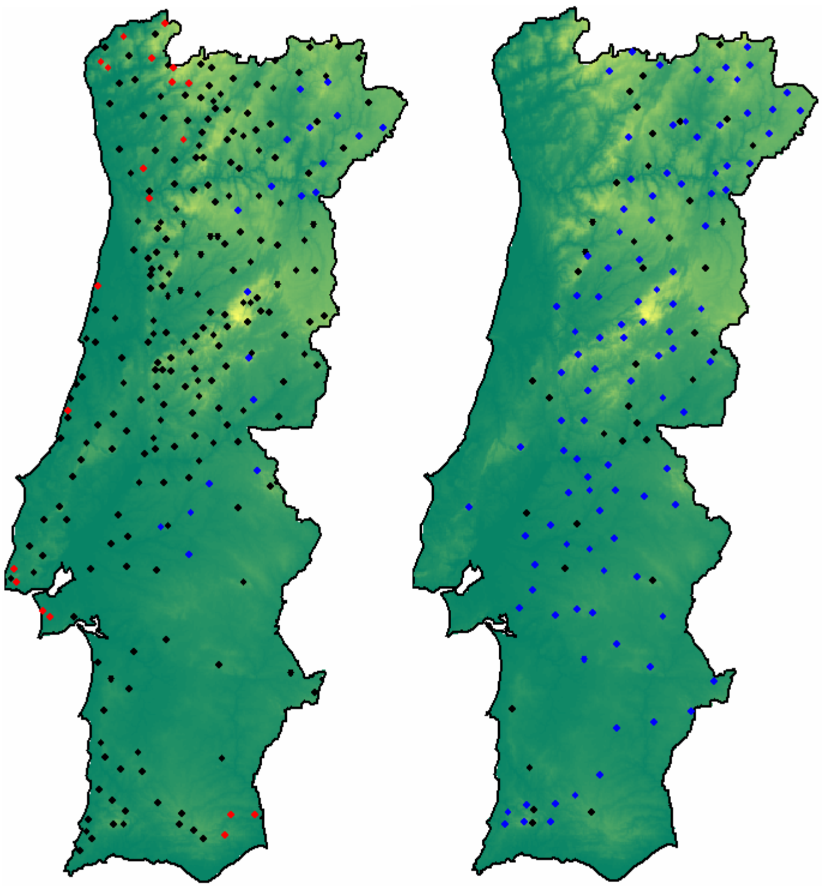

Figure 7—Left: Reposition proposal; sites to remove are marked red, new sites to add are marked blue. Right: New global configuration proposal. Sites that belong in current NLTN are marked black, in both cases.

Conclusions

The first and most important conclusion of this work is that the algorithms developed were in fact essential tools to use in the analysis and elaboration of proposals to improve the NLTN performance. These algorithms proved to be effective in the calculation of several types of proposals, providing optimal solutions in useful time.

As concern to the NLTN itself we concluded that its configuration is not optimized to current surveillance needs, having a significant percentage of sites which give a very low contribution to the network capabilities. The presented proposals can either increase greatly NLTN performance or reduce its costs.

Finally, we concluded that the presented methodology and algorithms can be applied to any surveillance network, either to evaluate its performance or to propose optimal changes.

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